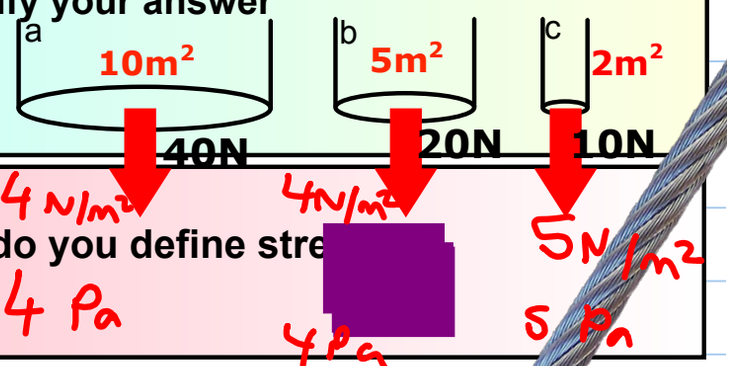
(c)	stress, strain and ultimate tensile strength		
(d)	**(i)**	Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$, $E = \frac{\sigma}{\varepsilon}$	*M3.1*
	(ii)	techniques and procedures used to determine the Young modulus for a metal	**PAG2**
(e)	stress–strain graphs for typical ductile, brittle and polymeric materials		*M3.2* HSW8
(f)	elastic and plastic deformations of materials.		HSW4, 5, 9, 12 Investigating the properties of materials **PAG2**

(6) M - Define and calculate stress and strain
(7) S - Calculate the Young's modulus of material and say what it means.
(8) C - Interpret a stress strain graph in terms of young's modulus.

Stress, strain and young's modulus

STARTER: Which cable is under the most stress. Justify your answer



Extension: How do you define stre

Tensile Stress is defined as the force applied per unit cross sectional area

$$\text{stress} = \frac{\text{Force}}{\text{cross sectional area}} \qquad \sigma = \frac{F}{A}$$

Force: N

cross sectional area: m^2

stress: Nm^{-2} or.... Pa

Now calculate the tensile stress of each cable

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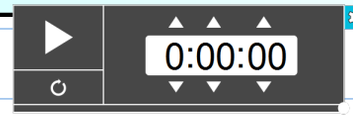
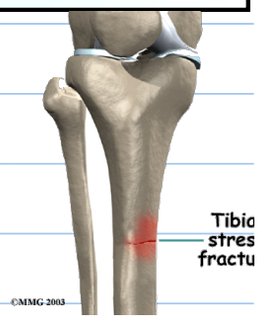
Stress Check





In pairs **estimate** the stress in your leg bone when standing up. Show all you working and be ready to justify your approximations.

Explain why your leg bones need to withstand greater stresses.

Ex: Start on this Q

A 70kg man jumps horizontally from a wall 2m high, lands on both feet together and takes 0.1 s to come to rest. The cross-sectional area of the bones in each of his lower legs is 30 cm^2.

synoptic link

(a) How fast is he moving **vertically** just as he reaches the ground?

(b) What is his average deceleration when landing?

(c) What is the average force exerted as he comes to rest?

(d) What is the **stress** in his legs?

Figure 2.

0.65 MPa
650 000 Pa

Table 1.

Bone	Test	Male		Female	
		σ_R [MPa] (ex)	σ_R [MPa](F.E.M.)	σ_R [MPa](ex)	σ_R [MPa] (F.E.M.)
Femur	*Compresion*	1.6005	1.6806	1.587	1.6155
	Traction	4.4168	4.3995	4.4286	4.3407
	Binding	4.0218	4.1003	4.0328	4.1134
Tibia	*Compresion*	0.6506	0.6592	0.6458	0.6554
	Traction	1.4872	1.4501	1.4722	1.4437
	Binding	4.2616	4.2561	4.2732	4.3159

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Strain

Tensile strain is defined as the fractional change in the original length of a wire / material

$$\text{strain} = \frac{\text{extension}}{\text{original length}}$$

extension: m

strain: no units

original length: m

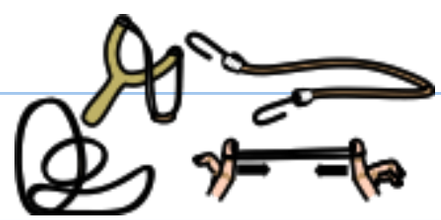
Ex: Identify the units

$= \frac{8}{10} = 0.8$

Quick check

A rubber band is stretched from 10cm to 18cm long. What is the strain?

Extension: Explain the significance of using the correct SI unit here in your calculation..



(6) M - Define and calculate stress and strain
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(8) C - Interpret a stress strain graph in terms of young's modulus.

Young's Modulus

The **young modulus** is defined as the ratio of stress to strain. It is a **constant** for a material and a measure of the **stiffness** of a material

high Y.M. = v. stiff, high stress, small strain.

$$YM = \frac{\text{stress}}{\text{strain}} = \frac{\sigma}{\varepsilon} = \frac{F / A}{x / L}$$

stress: N/m^2 or Pa

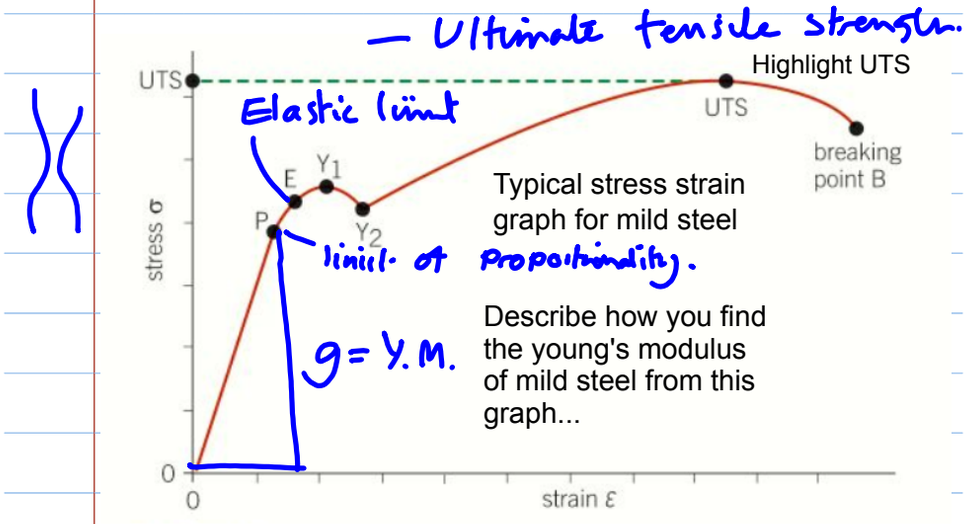
Unit? N/m^2 or Pa

strain: No unit.

Can you order these materials from highest to lowest youngs modulus: Ex: estimate them?

rubber	diamond	steel
0.1GPa	1000GPa	200GPa

click for answer



Typical stress strain graph for mild steel

Describe how you find the young's modulus of mild steel from this graph...

Example

Question

A load of 20 N on a metal wire of length 3.0 m and cross-sectional area 8.0×10^{-7} m^2 produces an extension of 0.10 mm. Calculate

a the tensile stress in the wire

b the tensile strain

c the Young modulus of the metal

d the elastic potential energy stored in the wire when it is extended.

(6) M - Define and calculate stress and strain
(7) S - Calculate the Young's modulus of material and say what it means.
(8) C - Interpret a stress strain graph in terms of young's modulus.

Questions

1 Calculate the stress in a wire of cross-sectional area $2.0 \times 10^{-6}\ m^2$ when it is subject to a force of 12 N. *(1 mark)*

2 Calculate the strain produced in a metal bar of Young modulus $1.2 \times 10^{11}\ N\ m^{-2}$ when it is subject to a tensile stress of $1.8 \times 10^{6}\ N\ m^{-2}$. *(2 marks)*

3 **a** Calculate the force which will produce an extension of 0.30 mm in a steel wire with a length of 4.0 m and a cross-sectional area of $2.0 \times 10^{-6}\ m^2$. *(2 marks)*

Young modulus of steel $= 2.1 \times 10^{11}$ Pa

b Calculate the energy stored in the stretched wire. *(2 marks)*

F x L

4 A load of 15 N produces an extension of 0.10 mm in a metal wire 10 m in length.

If the Young modulus of the metal is 1.8×10^{11} Pa, calculate

a the cross-sectional area of the wire *(2 marks)*

Y.M.

b the diameter of the wire. *(2 marks)*

Ex: How could you measure the young's modulus of spiders silk?

$$Y.M = \frac{LF}{Ax}$$

$$A = \frac{LF}{Y.M \times x} = \frac{10 \times 15}{1.8 \times 10^{11} \times 0.1 \times 10^{-3}}$$

$$= 8.3 \times 10^{-6}\ m^2$$

Answer

Step 1

Write out the values given in the question, converting them where necessary.

$F = 20$ N

$L = 3.0$ m

$A = 8.0 \times 10^{-7}$ m^2

$x = 0.10$ mm $= 1.0 \times 10^{-4}$ m

a *Step 2*

Calculate the tensile stress.

$$\sigma = \frac{F}{A}$$

$$= \frac{20}{8.0 \times 10^{-7}}$$

$= 2.5 \times 10^7$ Pa

b *Step 3*

Calculate the tensile strain.

$$\varepsilon = \frac{x}{L}$$

$$= \frac{1.0 \times 10^{-4}}{3.0}$$

$= 3.3 \times 10^{-5}$

c *Step 4*

Calculate the Young modulus.

$$E = \frac{\sigma}{\varepsilon}$$

$$= \frac{2.5 \times 10^7}{3.33 \times 10^{-5}}$$

$= 7.5 \times 10^{11}$ Pa

d *Step 5*

Calculate the stored elastic potential energy in the stretched wire.

$$\text{elastic energy stored} = \frac{1}{2} F x$$

$$= \frac{1}{2} \times 20 \times 1.0 \times 10^{-4}$$

$= 1.0 \times 10^{-3}$ J

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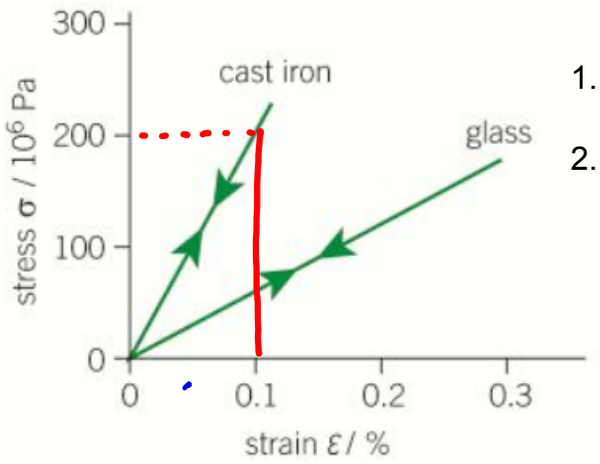
Plenary



1. Compare the properties of glass and cast iron.
2. Estimate the YM of cast iron. Show your working

$\varepsilon = \frac{0.1}{100}$

Support: think in terms of stiffness, strength and type of deformation

SA

Iron	Glass
elastic/brittle	elastic/brittle
cannot tell strength	cannot tell strength
Stiffer	less Stiff

gradient = dy/dx = stress/strain = YM

YM = 200x106/0.001

YM =